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(54) METHOD AND SYSTEM FOR THE FABRICATION OF EXTRUDABLE SYMTHETIC WOOD

VERFAHREN UND VORRICHTUNG ZUR HERSTELLUNG VON EXTRUDIERBAREN SYNTHETISCHEN HOLZ

METHODE ET APPAREIL POUR LA FABRICATION DE LIGNEUX SYNTHETIQUE EXTRUDABLE

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Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. Application Serial No. 08/150,860, filed November 12, 1993, the full text of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention generally relates to wood-like products. The invention particularly relates to an extruded wood-polymer composite material suitable for use in place of natural wood. In addition, the invention relates to a process for manufacturing the composite materials.

DESCRIPTION OF THE PRIOR ART

[0003] Although wood is a naturally reproducible resource, the demand for wood is consistently high and the supply of good wood for construction purposes is beginning to diminish. Accordingly, there is an increasing urgency to find alternative sources of wood.

[0004] One alternate source is through the production of artificial wood from a mixture of ingredients including recycled wood scraps such as wood meal, wood chips, saw dust and newspapers, which are by-products of industrial wastes in other industries using natural wood products. However, the utilization of recycled wood in the artificial lumber industry is not yet effective for a number of reasons including inefficient manufacturing processes and defects in the resulting products.

[0005] Prior art attempts to make artificial wood include a technique where wood is mixed with a thermoplastic resin. According to the prior art, a thermoplastic resin such as polyethylene or polypropylene is mixed with roughly-ground woody or fibrous cellulosic material obtained by chopping waste paper, newspaper, corrugated board or compressed board paper to a small size by means of a cutter. The mixture is introduced into a heated mixer followed by kneading. As the kneading proceeds, the temperature of the mixed materials rises due to the heat generated by friction and shear. As a consequence, the moisture in the waste paper vaporizes, and the waste paper is dried. At the same time, molten thermoplastic resin is mixed into the waste paper. The mixture is then transferred to another mixer and cooled with water to about 20°C to obtain the composition.

[0006] A disadvantage to this process is that the wood meal and the resin are dispersed in a bulky manner resulting in a non-uniform dispersion of the ingredients. Additionally, the thermoplastic resin can be subjected to degradation by oxidation in a heated, molten state. The cellulose may degrade as well.

[0007] There are other processes disclosed in the prior art for manufacturing artificial wood products. For example, U.S. Patent No. 4,091,153 to *Holman* is directed to producing boards of artificial lumber. The boards are composed of a ligneous fibrous material mixed with a thermosetting resin. In this process, the resin is heat activated and is compressed into arcuate columns to imitate the grain of wood.

[0008] U.S. Patent No. 4,686,251 to *Ostermann et. al.* also describes a method to produce decorative panels. In the process an epoxy resin is combined with fragments or pieces of wood that were previously heated to a temperature higher than the peak temperature of the resin-reagent mixture. Decorative objects may be produced from the process.

[0009] U.S. Patent No. 5,055,247 to *Ueda et. al.* describes a process for producing a woody molding that includes adding a dibasic acid anhydride to a woody material such as wood meal in the presence of sodium carbonate. An esterified woody material is then kneaded and heat and press molded.

[0010] A similar process is disclosed in U.S. Patent No, 4,708,623 to *Aoki et. al.* which discloses a process and apparatus for producing a uniform organic-filler blended resin composition. The originating materials are an organic filler such as waste paper and a thermoplastic resin. The process involves an extruder providing many projections and grooves that knead the materials causing them to combine more completely.

[0011] A method for compression molding articles from lignocellulosic materials is disclosed in U.S. Patent No. 5,002,713 to *Palardy et. al.* This patent discloses a method to produce particle board panels made from wood flakes or other lignocellulosic materials with a high moisture content. The method utilizes a catalyst to accelerate the reaction binding the flakes or particles.

[0012] U.S. Patents No. 5,151,238 to *Earl et. al.*, 5,087,400 to *Theuveny* and 3,908,902 to *Collins et. al.* all disclose processes for producing a composite material in which cellulosic substrate is treated with a polymer and then compressed.

[0013] U.S. Patents No. 5,088,910 to *Goforth et al.* and 5,082,605 to *Brooks et al.* disclose a method for making a synthetic, composite wood product in which scrap wood or cellulosic fibres are combined with waste plastic materials, preferably high or low density polyethylene. U.S. Patent No. 5,096,406 to *Brooks et al.* is directed to the extruder

assembly used in the process disclosed in the '605 patent to *Brooks et al.*

[0014] In the prior art processes the composites are generally processed at high temperatures which slow down the process and cause the polymer to degrade. Further, these processes require uniform, sorted raw material which also slows down the operation.

[0015] WO 90/06218 discloses a process and system on which the pre-characterising section of claims 1 and 20 are based.

[0016] The present invention overcomes many of the deficiencies of the prior art by providing a process for the production of a composite material from particles of cellulosic material comprising the steps of:

a. combining the cellulosic material with a sufficient amount of thermoplastic material to form a combined product;
b. extruding the combined product under sufficient conditions to blend the combined product together into a homogenous mixture;
c. passing the homogenous mixture through a transition die including an expanding conduit, thereby preshaping and expanding the homogenous mixture;
d. passing the homogenous mixture through a stranding die to form a plurality of adjacently positioned strands of homogenous mixture; and
e. passing the plurality of strands through a moulding die for a time sufficient to compress the strands together and bond the strands to each other; said process characterised in that the step of extruding is carried out at a temperature substantially lower than the plasterizaton temperature of the thermoplastic.

[0017] The present invention is also directed to a low temperature extruder system for forming a composite molded extrudate from a mixture of organic fibrous material and thermoplastic material, comprising:

a. a hopper to receive and form a mixture of the organic fibrous material and the thermoplastic material;
b. an extruder wherein the mixture is extruded, the extruder having an extruder outlet;
c. a first transition die including a conduit with a first conduit end adapted to the shape of the extruder outlet, the conduit expanding from the first conduit end to a second conduit end, wherein the mixture is expanded and preformed;
d. a second stranding die (40), connected to the second conduit end, provided with a plurality of stranding apertures (42) of the same size and constant shape through said stranding die to receive and shear the formed mixture into a plurality of individual strands each having an exterior surface;
e. a third molding die, connected to the second stranding die, provided with an aperture to receive and compress the individual strands into a final molded shape; and
f. a fourth shaping die, connected to the third molding die, provided with an extrudate shape-forming aperture for molding the molded extrudate; and characterised in further comprising:
g. control means for controlling the extension parameters to keep the temperature of the extrudate below the plasticization temperature of the extrudate.

[0018] The product has an appearance similar to wood, and may be sawed, sanded, shaped, turned, fastened and/or finished in the same manner as natural wood.

[0019] A primary advantage of the present invention is that the starting mixture can be continuously processed at lower temperatures than those typically used to combine cellulosic fibrous material with polymeric materials. Because of the low temperature, the process is less expensive, which makes it more economically efficient and also more energy efficient. The cross-linking chemistry that is used in the extrusion process is more economically efficient than the relatively expensive compression type molding.

[0020] Because of the low temperatures, the die system configuration, and the individual strands used to form the final shape, traditional flow problems associated with solid part extrusion are eliminated. Very sharp edges and corners and very intricate shapes are therefore possible directly out of the die system.

[0021] Other advantages are as follows: (1) virtually any type of virgin or recycled material may be used for either the cellulosic fiber or thermoplastic components; (2) the resulting product does not expand after leaving the molding die; (3) any desired length of finished material may be manufactured using the extrusion process as opposed to the fixed lengths obtained from compression type molding; and (4) because it is largely inert, the product will also outlast wood many times over. It is not only resistant to rot and decay, it is also impervious to termite attack.

[0022] The present invention produces a composite product that allows for improved "workability" such as sanding, sawing, etc. The improved workability is brought about by the reaction between the bonding agents and the fibrous strands.

[0023] The cellulosic fiber-polymer product may be used for decorative moldings inside or outside of a house, picture frames, furniture, porch decks, window molding, window components, door components, roofing systems and any

other type of use where structural requirements do not exceed the physical properties of the composite.

[0024] Reference is now made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] In the drawings:

Figure 1 is a flow chart illustrating the process of the present invention.
Figure 2 is a cross-sectional view of the die system of the present invention illustrating each of the die plates.
Figure 3 is a cross-sectional view of the die system of Figure 2.
Figure 4 is a cross-sectional view of the adapter die plate of Figure 2.
Figure 4A is a front elevated view of the adapter die plate of Figure 4, taken along lines 4A-4A of Figure 4.
Figure 4B is a rear elevated view of the adapter die plate of Figure 4, taken along lines 4B-4B of Figure 4.
Figure 5 is a cross-sectional view of the transition die plate of Figure 2.
Figure 5A is a front elevated view of the transition die plate of Figure 5 taken along lines 5A-5A of Figure 5.
Figure 5B is a rear elevated view of the transition die plate of Figure 5 taken along lines 5B-5B of Figure 5.
Figure 6 is a cross-sectional view of the stranding die plate of Figure 2.
Figure 6A is a front elevated view of the stranding die plate of Figure 6 taken along lines 6A-6A of Figure 6.
Figure 6B is a rear elevated view of the stranding die plate of Figure 6 taken along lines 6B-6B of Figure 6.
Figure 6C is a front elevated view of a first alternative embodiment of the stranding die plate of Figure 2.
Figure 7 is an exploded perspective view of a second alternative embodiment of the stranding die plate of Figure 2.
Figure 8 is a perspective view of the rear plate of the stranding die plate of Figure 7.
Figure 9 is a partial cross-sectional view of the stranding die plate of Figure 8 taken at lines 9-9 of Figure 8.
Figure 10 is a cross-sectional view of the molding die plate of Figure 2.
Figure 10A is a front elevated view of the molding die plate of Figure 10 taken along lines 10A-10A of Figure 10.
Figure 10B is a rear elevated view of the molding die plate of Figure 10 taken along lines 10B-10B of Figure 10.
Figure 11 is a cross-sectional view of the setting die plate of Figure 2.
Figure 11A is a front elevated view of the setting die plate of Figure 11 taken along lines 11A-11A of Figure 11.
Figure 11B is a rear elevated view of the setting die plate of Figure 11 taken along lines 11B-11B of Figure 11.
Figure 12 is a perspective view of a spray head system illustrated in Figures 1 and 2.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The present invention is directed to a wood-polymer composite product, as well as the process and machine for making the product. The invention is specifically directed to the combination of a low-temperature extruder and the die system.

[0027] The unique die system of the present invention allows the combined starting materials to bond into a shaped, homogeneous product. The extruded material is introduced through the adapter die and reshaped and slightly expanded in the transition die. The material is then separated into individual strands in the stranding die. The shearing action of the stranding die creates local high temperatures on the exterior surface of each individual strand, while leaving the bulk interior of each strand at a much lower temperature. The strands are then compressed and shaped in the molding die. The flow of the extruded material through the die system is balanced by passing the extruded material through the transition die prior to passage through the stranding die and passing the stranded material through a molding die subsequent to passage through the stranding die. The die system configuration equalizes the flow at the outside edges of the shaped composite material with the flow at the center of the shaped composite material to produce a product having a uniform substructure that is similar to the grain in a true wood product.

[0028] As the individual strands are pressed against each other, the localized high temperature present on the outer surface of each strand causes the strands to bond to adjacent strands. In the setting die, the final shape is maintained while the individual strands and the individual cellulose molecular chains continue to bond together. The formed product is then cooled in a cooling tank and transported over rollers by a pulling mechanism. The cooled product is cut into desired lengths.

[0029] The cellulosic fibrous-polymer composite material of the present invention is characterized by having a higher cellulosic fiber content than normally recognized in the prior art. While the prior art normally requires a material content including approximately 50% fiber to 50% thermoplastic material, the material of the present invention has a higher fiber content. The material can have a up to a 1:0 fiber/thermoplastic content by employing the continuous low temperature extrusion process of the present invention and the proper mix of starting materials.

[0030] The basic process requires mixing of basic types of raw materials including cellulosic fibers and thermoplastic

materials. Cross-linking agents and process lubricants may also be included in the basic mixture.

Cellulosic Materials:

[0031] One advantage of the present invention is that it can incorporate virtually any kind of waste cellulosic material from sawdust to pond sludge and newspapers. As described earlier, any cellulosic material may be used as a raw material including old newspapers, alfalfa, wheat pulp, wood chips, wood particles, wood flour, wood flakes, wood fibers, ground wood, wood veneers, wood laminates, kenaf, paper, cardboard, straw, and other cellulosic fibrous materials.

[0032] The cellulosic fibrous material may also comprise refined cellulose such as cotton or viscous and plant fibers such as kenaf, bamboo or palm fiber, straw or any other cellulosic fibrous material.

[0033] Prior to being combined with the other starting materials, the cellulosic materials should be dried to a moisture content between approximately 1% and 9%. A preferred moisture content is no more than 2%. Drying technologies are known to the art. A suitable example is a desiccant dryer manufactured by Premier Pneumatics, Inc. (Allentown, PA.).

Thermoplastic Materials:

[0034] The thermoplastic materials serve primarily as a process fluidizer. Most types of thermoplastic materials may be used, examples of which include multi-layer films, virgin thermoplastics such as polyethylene, polypropylene, polyvinyl chloride (PVC), low density polyethylene (LDPE), ethyl-vinyl acetate and waste plastic sawdust from other industries as well as other recyclable polymer materials. Although thermoplastic materials are a preferable component in the make-up of the starting materials, it is not required. As long as the starting material includes a sufficient amount of cross-linking agents and lubricants to "plasticize" the mixture in the extruder, the starting materials do not necessarily require the use of thermoplastic materials.

[0035] The ratio of cellulosic fibers to the thermoplastic material is, therefore, between approximately 4:1 and 1:0. Preferably the ratio between the cellulosic fibers to the thermoplastic material is approximately 1:1.

Cross-Linking Agents:

[0036] The cross-linking agent serves to strengthen the bond between the several strands of the cellulosic fibers into a final homogenous product. The cross-linking agents bond across the pendent hydroxy groups on the cellulose molecular chain. Cross-linking agents must have the characteristics of forming a strong bond at relatively low temperatures. Examples of cross-linking agents include polyurethanes such as isocyanate, phenolic resins, unsaturated polyesters and epoxy resins and combinations of the same. The phenolic resins may be any single stage or two stage resin preferably with a low hexane content. Although the starting material may comprise a cross-linking agent to strengthen the bonds between the cellulosic fiber strands, the cross-linking agent is not required to form the final product contemplated by the inventive process as long as thermoplastic and cellulosic materials are included in the starting material.

Lubricants:

[0037] Lubricants, which are common commercial lubricants known to the art of plastic processing, behave as a process aid. Examples of typical lubricants include zinc stearate, which is an internal lubricant and paraffin-type wax, which is an exterior lubricant.

Other Materials:

[0038] Other materials, which can be added, are known to the art of extrusion and include accelerators, inhibitors, enhancers, compatibilizers and blowing agents.

[0039] Accelerators, inhibitors, enhancers and compatibilizers are agents which control the speed at which the cross-linking agents work.

[0040] Accelerators are added to increase the speed of the cross-linking reaction. Examples of accelerators include amine catalysts such as Dabco® BDO (Air Products, Allentown, PA.) and DEH40® (Dow Chemical).

[0041] Inhibitors are added to retard the speed of the cross-linking reaction. Example of known inhibitors include organic acids such as citric acid.

[0042] Enhancers are used to increase the reactivity between components. Examples of enhancers include cobalt derivatives.

[0043] Compatibilizers are used to form a more effective bond between cellulosic materials and thermoplastics. Examples of compatibilizers include ethylene-maleic anhydride copolymers.

[0044] Blowing agents are added to decrease density. An example of a blowing agent is CELOGEN® TSH (Uniroyal Chemical).

[0045] There are many formulation recipes which can be prepared for the starting mixture. The following table includes four examples (expressed in Kg (pounds) of material):

RECIPE	I		II		III		IV	
Wood Flour	11.25	(25.00)	11.25	(25.00)	11.25	(25.00)	11.25	(25.00)
Polyethylene	6.75	(15.00)	5.63	(12.50)	6.75	(15.00)	3.38	(7.50)
Zinc Stearate	0.34	(.75)	0.68	(1.50)	0.45	(1.00)	0.56	(1.25)
Wax	0.23	(.50)	0.23	(.50)	0.23	(.50)	0.34	(.75)
Phenolic Resin	0.68	(1.50)	0.00	(.00)	0.00	(.00)	3.83	(8.50)
Isocyanate	0.23	(.50)	0.45	(1.00)	0.00	(.00)	0.00	(.00)
Epoxy Resin	0.00	(.00)	0.00	(.00)	1.13	(2.50)	0.00	(.00)
Catalyst	0.00	(.00)	0.00	(.00)	0.08	(0.75	0.00	(.00)

[0046] The preferred formulation is as follows:

MATERIAL	AMOUNT (PARTS)
Wood Flour (40 Mesh)	100.0
Polyethylene (HDPE)	40.0
Zinc Stearate	3.0
External Wax	2.0
Phenolic Resin	6.0
Polyurethane	2.0

[0047] The wood flour is dried to 2% moisture content or less. The polyethylene (HDPE) and polyurethane are mixed in a ribbon blender until absorbed, approximately five minutes. The remaining ingredients are added to the mixture, and blended for approximately three minutes or until evenly mixed under conditions known to the art

[0048] Referring now to the figures, wherein the same reference numbers relate to the same or similar features throughout the figures, Fig. 1 illustrates a flow diagram of the process of the present invention.

Hopper:

[0049] In the first step, the cellulosic fiber and thermoplastic raw materials are first shredded according to methods known to the art, physically mixed with cross-linking agents and process lubricants in a blender 8, and subsequently placed into a feed hopper 10.

[0050] The cellulose materials are comminuted by conventional particle reduction equipment known to the art. These may include grinders, ball mills, choppers or other equipment capable of reducing the fiber to a flour of a distinct particle size or range of sizes. A 40-mesh flour appears to be the best form but good results have been obtained with both coarser and finer materials.

[0051] The mixing of the materials prior to loading the extruder may be accomplished by any simple mixing device. No heat is required during mixing and only an even distribution of the various components is required. A drum tumbler may be used for small quantities or a larger batch-type mixer such as a ribbon blender known to the art may be used.

[0052] A typical feed hopper used in this process may be a gravity feed, starve feed or force feed (also known as a "crammer") hopper, depending on the flow characteristics of the particular compound.

Extruder:

[0053] This mixture of raw materials is then delivered to a heated extruder 12. The extruder 12 utilizes low temperature mixing and extruding. This is unique in that most plastic mixing processes require mixing at a plasticization temperature, which is quite high. The present mixing temperature is substantially lower, preferably around 80°C (180°F). The material passing through the extruder creates a mass of homogenous material at a certain temperature, approximately 85-90°C (185° - 200°F) depending upon the particular compound.

[0054] The present invention can be processed with any capacity extruder. A counter-rotating and intermeshing twin screw, high pressure, extruder manufactured by Cincinnati Milacron (CM-55-HP) may be used in the preferred embodiment.

[0055] Preferably, the process is accomplished by twin screw extruders, which are heated to process temperatures sufficient to blend the product together into a homogenous mixture at low temperature.

Temperature:

[0056] In the low temperature, high pressure extruder, the materials are blended, heated and then forced into a die system. Unlike the intended or prior art purpose of typical heated extruders, which heat the product to plasticization temperatures, the extruder of the present invention requires only that the product be brought to a blending or homogenizing temperature, which is less than plasticization temperatures.

[0057] The temperature of the extruder used in the present invention is controlled by the extrusion speed, external extruder heaters, shearing action and heaters in the die system and monitored by thermocouples and other monitoring circuits. The purpose of the thermocouples is to monitor the heat at each station. The bulk temperature is significantly lower, e.g., about 65° - 90°C (150° - 200°F), than the "true melt" of the thermoplastic fluidizers.

Flow Rate:

[0058] The flow rate of the extruder may be between about 45 and 1125kg (100 and 2500 pounds) per hour. In the preferred embodiment the flow rate is approximately 270kg (600 pounds) per hour with a temperature at approximately 80°C (180°F).

[0059] The product leaving the extruder is essentially unbounded round stock. Various sized extruder orifices are available with a range from 25 millimeters (mm) to 72mm. In the preferred embodiment a 38mm orifice is used.

Die:

[0060] The materials are blended, heated and then extruded into a die system 14. The die system 14 is made up of a series of plates, which will be explained below with reference to Figs. 2 and 3. The unique die system 14 allows the starting materials to bond and form a shaped-homogeneous product. Each of the plates can be made of materials known to the art to accomplish the necessary purpose. Typical materials include cast iron and stainless steel.

[0061] The amount of volume of material allowed into the die system 14 is controlled by the adapter die 16, which is illustrated in detail in Figs. 4, 4A, and 4B, and further by the shapes of the transition die 25, stranding die 50 and molding die 78, which are explained with reference to Figs. 2 and 3. As previously described, this die configuration functions to balance the flow of the material thereby allowing for the production of uniform end product.

[0062] Fig. 3 illustrates a cross-sectional view of the die system 14 of the present invention. As previously indicated, the individual die pieces contained within the die system 14 comprise the adapter die 16, the transition die 25, the stranding die 50, the molding die 78, and the setting die 94. The individual die pieces are nested together to form one continuous die.

Extrusion Plate:

[0063] The adapter die 16 acts to connect the die system 14 to the extruder 12. As illustrated in Figs. 3 and 4, the adapter die 16 includes a front face 17, shown in Fig. 4A, a rear face 18, shown in Fig. 4B, and a conduit 19. The conduit 19 narrows in diameter from the front face 17 to the rear face 18.

[0064] Fig. 4A shows a front elevated view of the adapter die 16. The front face 17 of the adapter die 16 comprises a figure eight orifice 23, which can accommodate a twin screw extruder, at the end of the conduit 19 nearest the extruder 12. Bolt holes 20 are contained near the edge of the front face 17 of the adapter die 16 to secure the adapter die 16 to the extruder 12.

[0065] Fig. 4B shows a rear elevated view of the adapter die 16. The rear face 18 of the adapter die 16 comprises a circular orifice 24 which is located at that end of the conduit 19 which is nearest to the transition die 25. The rear face 18 of the adapter die 16 further comprises an extended portion 21 which is designed to nest within a shallow channel 26 which comprises part of the transition die 25. A second set of bolt holes 22 are contained within the extended portion 21 of the rear face 18 of the adapter die 16 to secure the rear face 18 of the adapter die 16 to the transition die 25.

[0066] The circular orifice 24 controls the volume of extruder material allowed into the die system 14. Typically, the circular orifice 24 is available in sizes ranging from 50mm to 300mm.

Transition Die:

[0067] The extruded material is reshaped and slightly expanded in the transition die 25, illustrated in Figs. 5, 5A, and 5B. Generally, the transition die 25 is a square-shaped metal plate, approximately 40mm (one and one-half inches) thick having a front face 28, a rear face 30 and bolt holes 32. The bolt holes 32 extend from the front face 28, through the material to the rear face 30. They are used to assemble all of the various dies into the die system and may be located in the same position on each die. The front face 28 also includes a shallow channel 26, previously described with reference to the adapter die 16, which allows the adapter die 16 to be seated within the transition die 25.

[0068] The transition die 25 further comprises a conduit 34 which transforms the combined material discharged from the round stock exiting the circular orifice 24 of the adapter die 16 to a shape more generally approaching that of the finished product. This function of the transition die 25 serves to equalize the flow rate at the outer edges of the extruded material with the flow rate at the center of the extruded material. The conduit 34 comprises a first circular shaped orifice 36 located at the front face 28 of the transition die 25 and a second oblong shaped orifice 38 located at the rear face 30 of the transition die 25. The oblong shape of the second orifice 38 approaches the shape of the finished product.

Stranding Die:

[0069] The material is then separated into individual strands in a stranding die 40. The stranding die 40 contains a plurality of apertures 42 and is illustrated in Figs. 6, 6A, and 6B. The standard stranding die 40 is a square-shaped metal plate, approximately 40mm (1-1/2 inches) thick, which comprises a front first face 44, a rear second face 46 and bolt holes 48 for assembly. The multiple apertures 42 pass through the stranding die 24 and are arranged in a manner which facilitates proper volume distribution for the final product.

[0070] Figs. 6A and 6B show the multiple apertures 42 contained within an oblong shaped area similar to the shape of the second orifice 38 contained within the transition die 25. All of the apertures 42 may be substantially round, are contiguous through the material substantially parallel to each other and maintain a constant shape from the front first face 44 to the rear second face 46. One preferred embodiment of the stranding die contains apertures which are approximately 3mm (one-eighth of an inch) in diameter. Ideally, the aperture size is dependent upon the size of the end structure. The aperture area of individual strands is constant throughout.

[0071] A first alternative embodiment of the stranding die 40 is shown in Fig. 6C. Here the multiple apertures 42 are not contained within an area defined by the shape of the second orifice 38 of the transition die 25. Instead, the multiple apertures 42 may be contained within any given area located within that area defined by the bolt holes 48. When the front face 44 of the stranding die 40 is secured to the rear face 30 of the transition die 25, the extruded material will be forced through the multiple apertures 42 which are contained within the area defined by the shape of the second orifice 38 of the transition die 25.

Gas-Evacuation Stranding Die:

[0072] In a second alternate embodiment, illustrated in Figs. 7-9, a gas-evacuation stranding die 50 facilitates removal of unwanted process gasses which are present when using volatile cross-linking agents. In the "gas-evacuation" embodiment, the stranding die is configured such that it facilitates removal of unwanted process gases which are present when using volatile cross-linking agents. This is particularly important for some of the products which emit gases during the processing.

[0073] As illustrated in Fig. 7, a gas-evacuation stranding die embodiment 50 comprises two metal plates, 52, 54, each approximately 40mm (1-1/2 inches) thick. The first plate 52 includes a front first face 56, a rear second face 58 and bolt holes 60 used for assembly to other dies. The first plate 52 also includes multiple stranding apertures 62 arranged in a manner which facilitates proper volume distribution for the final product. The rear second face 58 of the first plate 52 and a front first face 64 of the second plate 54 register with each other such that the stranding apertures 62 align. A channel 66 surrounds the perimeter of the stranding apertures 62 between the first plate 52 and the second plate 54 sealing the apertures 62.

[0074] The second plate 54 has a front first face 64 and a rear second face 68 with stranding apertures 62 aligned axially with the stranding apertures 62 located on the first plate 52. Also located on the first face 64 of the second plate 54 are channels 70 connecting each of the stranding apertures 62, in a grid-like pattern. Inlets 72 of vents 74 are disposed on the first face 64 within the channels 70, located at a mid-point between each of the stranding apertures 62 in the preferred embodiment. The vents 74 are of smaller circumference than the stranding apertures 62. Outlets 76 of vents 74 are disposed in the second face 68.

[0075] In either embodiment, the shearing action of the stranding die creates local high temperatures on the outside of each individual strand, while the interior bulk of each strand remains at a lower temperature. In the gas evacuation embodiment, the stranding die 50 is configured such that it facilitates removal of unwanted process gasses which are

present when using volatile cross-linking agents. The unwanted gasses evacuate through the channels 70 which direct the gasses to the inlets 72, passing the gasses through the vents 74 and out through the outlets 76.

[0076] As illustrated in Fig. 8, the preferred embodiment, the outlets 76 have a larger circumference than the inlets 72, with the vents 74 providing a gradual increase in circumference. The shape of the vents 74 provides a venturi-type system with the low-pressure outlets 76 supplying a vacuum to pull the unwanted gasses away from the strands.

Molding Die:

[0077] After the strands of homogenized material pass through the multi-apertured stranding die, they are compressed together in a molding die 78 to form the final shape. The heated, compressed cellulose molecular chains are then bound together. This bonding may be facilitated by cross-linking agents. The heat dissipates from the exterior of the surface of each strand to give a blended stock temperature, but only after the strands have bonded. The strands bond because of the higher external temperature, which then dissipates the heat through the whole profile of the forming product.

[0078] The strands are compressed and shaped in a molding die 78, shown in Figs. 10, 10A, and 10B. The heated outer surface of each of the strands acts to anneal the strands together. In addition, as the individual strands are compressed against each other, the localized high temperatures on the outer surface of each strand cause the bonding of the thermoset materials to pendent hydroxy units on the cellulose molecular chain. If cross-linking agents are included in the starting material, the cross-linking agents act to form an exothermic reaction on the outer surface of each strand thereby facilitating the bonding of the thermoset materials to pendant hydroxy units on the cellulose molecular chain.

[0079] The molding die 78 is a square-shaped metal plate 80, approximately 40 mm (one and one-half inches) thick having a front face 82, a rear face 84 and bolt holes 86 for assembly with the other dies in the system. The molding die 78 further comprises a conduit 88 having a first oblong shaped orifice 90 similar in shape to the second orifice 38 of the transition die 25 and a second orifice 92 which may be identical to the shape of the desired end product.

[0080] The first orifice 90 comprises part of the front face 82 of the molding die 78 while the second orifice 92 comprises part of the rear face 84 of the molding die 78. The front face 82 of the molding die 78 is secured to the rear face 58 of the stranding die 50. The conduit 88 functions to compress and transform the composite material extruded from the stranding die 50 to the shape of the finished product.

[0081] One of the main advantages to this process is that the molded product has virtually no expansion after it leaves the molding die. This is due to the low temperature processing in the extruder and die system.

[0082] Molding dies 78 of any shape are contemplated within this invention, including decorative household moldings such as crown moldings, chair rails, baseboards, door moldings, etc., picture frames, furniture trim and other products mentioned in this application.

Setting Die:

[0083] In the setting die 94, the final shape is maintained. If cross-linking agents are included in the starting material, the cross-linking agents continue to react in the setting die 94, thereby bonding the individual strands together. The setting die 94, illustrated in Figs. 11, 11A, and 11B, is a combination of two metal plates, a first plate 96 and a second plate 98 each approximately one and one-half inches thick joined by a hollow metal sleeve 100. The hollow cavity 102 contained within the metal sleeve 100 is configured in the shape of the final product.

[0084] Fig. 11A shows the front face 104 of each of the first and second plates 96,98 and Fig. 11B shows the rear face 106 of each of the first and second plates 96,98. Bolt holes 108 allow the front face 104 of the first plate 96 to be bolted and secured to the rear face 84 of the molding die 78.

Spray-Head System:

[0085] The preferred embodiment of the system of the present invention includes a spray-head system 95 positioned between the die system 14 and the cooling tank 110. Referring the Figs. 1, 2 and 12, there is shown a preferred spray-head system 95. The spray head may comprise any suitable configuration designed to a cooling fluid, such as water, antifreeze or another suitable liquid on the extrudate, i. e., the hot molded piece, as the extrudate leaves the die system 14.

[0086] In its preferred embodiment, the spray-head system comprises at least one and preferably three hollow-tubular and circularly-shaped spray rings 97. The spray rings are made of any material known to the art for transporting a cooling fluid. Suitable materials include plastics, rubber and metal, such as stainless steel or brass piping.

[0087] The spray rings 97 are connected to fluid input conduit 99, which passes pressurized fluid to the rings 97. As illustrated in Fig. 12, the fluid conduit 99 can be a central dispensing tube connected to a multiple of spray rings 97 by a connector unit 101. Each of the spray rings 97 include at least one and preferably a plurality of ejection ports 103,

for releasing the pressurized fluid 105 into the central environment defined by the shape of the spray rings 97.

[0088] In use, the molded extrudate exits the setting die 94 of the die system. Before the molded extrudate is given the opportunity to make substantial contact with air, the extrudate enters the spray-head system 95, which provides a spray of fluid 105 to soaks the extrudate. The pressure of the spray can be intense, similar to a spray from a typical garden hose, it can be mist-like atomizing spray, or it have an intermediate pressure depending upon the type of extrudate and the finish desired on the extrudate. If the spray hits the extrudate before the extrudate cools from the die system 14 and before the extrudate enters the atmosphere, the spray imparts a hardened gloss or glaze on the hot-molded extrudate and assists in preventing blistering and deformation on the surface of the molded extrudate. Without wishing to be restricted to any one reason for this occurrence, it is believed that the action of the spray on the molded extrudate prior to atmospheric contact, reacts with the urethane ingredient in the extrudate thereby imparting the hardened glaze on the product.

Cooling Tank:

[0089] After the molded product leaves the molding die, it is fed to a vented cooling tank 110, which is a conveyor system (known to the art) for conveying the material through a cooling process which may be under negative pressure especially if the product has hollow cores. A representative conveyor-type cooling tank is produced by Cincinnati Milacron. The cooling tank may include a vacuum water bath in the preferred embodiment. The length of the formed product is determined by the length of the cooling tank. Therefore, another advantage of the product is that it has potentially unlimited length in that it can continually be extruded from the system.

[0090] The formed product is cooled in the vented cooling tank and transported over rollers by a pulling mechanism 112 known to the art. The cooled product is then cut to the desired lengths using conventional means. The product can then be covered with a vinyl material, plastic laminate, paint or other suitable coverings known to the art. An inline crosshead extrusion die, known to the art, may be installed down-stream of the puller to apply a capstock of known compounds as an exterior finish.

[0091] The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described. Accordingly, all suitable modifications and equivalents fall within the scope of the invention.

Claims

1. A process for the production of a composite material from particles of cellulosic material comprising the steps of:

   a. combining the cellulosic material with a sufficient amount of thermoplastic material to form a combined product;
   b. extruding the combined product under sufficient conditions to blend the combined product together into a homogenous mixture;
   c. passing the homogenous mixture through a transition die (25) including an expanding conduit, thereby preshaping and expanding the homogenous mixture;
   d. passing the homogenous mixture through a stranding die (40) to form a plurality of adjacently positioned strands of homogenous mixture; and
   e. passing the plurality of strands through a moulding die (78) for a time sufficient to compress the strands together and bond the strands to each other;

   said process **characterised in that** the step of extruding is carried out at a temperature substantially lower than the plasticization temperature of the thermoplastic.

2. The process of claim 1, further comprising the step of passing the homogeneous mixture through an adaptor die (16) to control a volume of the homogeneous mixture allowed into the transition die (25).

3. The process of any one of the preceding claims, wherein each of the plurality of adjacent positioned strands has a surface temperature hotter than an interior temperature of each strand.

4. The process of any one of the preceding claims, wherein the stranding die is a multiple aperture die comprising means to increase the temperature of the outer surface of each of the strands that are formed in the die.

5. The process of any one of claims 1 to 3, wherein the stranding die (40) comprises multiple apertures (42) arranged in a manner to facilitate proper volume distribution for the strands, wherein all of the apertures (42) are substantially round.

6. The process of any one of claims 4 and 5, wherein the multiple apertures (42) each comprise a diameter of approximately 3mm (one-eighth of an inch).

7. The process of any one of the preceding claims, wherein the stranding die (40) is a gas-evacuation stranding die comprising means to facilitate the removal of unwanted process gasses which are present when using volatile cross-linking agents.

8. The process of any one of the preceding claims, comprising passing the homogenous strands through a setting die (94) for a time sufficient to bond the individual strands together to form a molded extrudate after the homogenous strands are passed through the molding die (78).

9. The process of any one of the preceding claims, further comprising cooling the formed product, preferably under negative pressure.

10. The process of claim 9, comprising spraying the molded extrudate with a cooling fluid sufficient to impart a hardened glaze on the molded extrudate, which cooling fluid is preferably water.

11. The process to claim 10, comprising spraying the molded extrudate prior to exposing the extrudate to air.

12. The process of any one of the preceding claims, wherein the combined product is extruded at a temperature between about 65°C (150°F) and 90°C (200°F) and more preferably at a temperature of about 80°C (180°F).

13. The process of any one of the preceding claims, further comprising drying the cellulosic material prior to step a. to a moisture content between about 1% and 9%, preferably to a moisture content of 2%.

14. The process of any one of the preceding claims, wherein the cellulosic material is selected from the group consisting of newspapers, alfalfa, wheat pulp, wood flour, wood flakes, wood fibres, ground wood, wood veneers, wood laminates, paper, cardboard, straw, and other cellulosic fibrous materials.

15. The process of any one of the preceding claims, wherein the thermoplastic material is selected from the group consisting of multi-layer films, poly-vinyl chloride, polyolefins, ethyl-vinyl acetate and waste plastic sawdust.

16. The process of any one of the preceding claims, wherein the ratio of cellulosic material to thermoplastic material is between approximately 4:1 and 1:0.

17. The process of any one of the preceding claims, further comprising combining the cellulosic material with the thermoplastic material in the presence of a cross-linking agent, which agent is preferably selected from the group consisting of polyurethanes, phenolic resins, unsaturated polyesters and epoxy resins.

18. The process of any one of the preceding claims, further comprising combining the cellulosic material with the thermoplastic material in the presence of a lubricant, which lubricant is preferably selected from the group consisting of zinc stearate and paraffin-type wax.

19. The process of any one of the preceding claims, further comprising combining the cellulosic material with the thermoplastic material in the presence of one or more of the following: accelerators, inhibitors, enhancers, compatibilizers and blowing agents.

20. The process of claim 1 wherein the extrudate is more than 50% cellulosic material.

21. The process of claim 20 wherein approximately two-thirds of the extrudate is cellulosic material and approximately one-third thermoplastic material.

22. The process of claim 21 wherein the cellulosic material is selected from the group consisting of newspapers, alfalfa, wheat flour, wood-flour, wood pulp, wood chips, sawdust, wood particles, paper, refined cellulose such as cotton

and plant fibres such as bamboo.

23. The process of claim 21 wherein the thermoplastic material is selected from the group consisting of multi-layer film, food wrappers, polyolefins, ethyl-vinyl acetate and plastic sawdust.

24. The process of any one of claims 1 to 9 or 20 to 23 further comprising the step of manufacturing said composite to form an article.

25. A low-temperature extruder system for forming a composite molded extrudate from a mixture of organic fibrous material and thermoplastic material, comprising:

    a. a hopper to receive and form a mixture of the organic fibrous material and the thermoplastic material;
    b. an extruder (12) wherein the mixture is extruded, the extruder having an extruder outlet;
    c. a first transition die (25) including a conduit (34) with a first conduit end adapted to the shape of the extruder outlet, the conduit expanding from the first conduit end to a second conduit end, wherein the mixture is expanded and preformed;
    d. a second stranding die (40), connected to the second conduit end, provided with a plurality of stranding apertures (42) of the same size and constant shape through said stranding die to receive and shear the formed mixture into a plurality of individual strands each having an exterior surface;
    e. a third molding die (78), connected to the second stranding die (40), provided with an aperture to receive and compress the individual strands into a final molded shape; and
    f. a fourth shaping die (88), connected to the third molding die, provided with an extrudate shape-forming aperture for molding the molded extrudate; and **characterised in** further comprising:
    g. control means for controlling the extrusion parameters to keep the temperature of the extrudate below the plasticization temperature of the extrudate.

26. The low temperature extruder system of claim 25 further comprising an adapter die (16) located between the extruder (12) and the first transition die, the adapter die (16) being provided with an aperture to control the amount of mixture entering the first transition die.

27. The low temperature extruder system of claim 25 or 26 wherein the first transition die (25) comprises a first front face having a generally round orifice and a second rear face having an orifice similar to a shape of a finished product.

28. The low temperature extruder system of any one of claims 25 to 27 wherein the third molding die (78) comprises a first front face equivalent in shape to the second rear face of the first transition die (25) and a second rear shape-forming face to form the shape of the molded extrudate.

29. The low temperature extruder system of any one of claims 25 to 28 wherein the second stranding die (40) comprises a first surface (64) and a second surface (68), comprising:

    a. a plurality of gas evacuation channels (70) located on the first surface of the second die to receive and evacuate gases discharged from shearing the formed mixture; and
    b. a plurality of gas evacuation vents (74), having inlets (72) located on the first surface connected to the gas channels and outlets (76) located on the second surface, for receiving and evacuating gases from the gas evacuation channels.

30. The low temperature extruder system of claim 29 wherein the gas evacuation vent outlets (76) have a larger circumference than the inlets (72), providing a venturi effect to increase gas evacuation efficiency.

31. The low temperature extruder system of claim 29 wherein the gas evacuation channels (70) are connected to the stranding apertures (42) in a grid formation.

32. The low temperature extruder system of claim 29 wherein the gas evacuation vents (74) are located substantially at a midpoint between the stranding apertures (42).

33. The low temperature extruder system of any one of claims 25 to 32 further comprising a spray head system (95) for receiving the molded extrudate passing from the fourth shaping die.

Patentansprüche

1. Verfahren zur Herstellung eines Verbundmaterials aus Teilchen eines Cellulosematerials, umfassend folgende Stufen:

   a. Vereinigen des Cellulosematerials mit einer ausreichenden Menge eines thermoplastischen Materials unter Bildung eines vereinigten Produkts;
   b. Extrudieren des vereinigten Produkts unter ausreichenden Bedingungen, um das vereinigte Produkt zu einem homogenen Gemisch zu vermischen;
   c. Durchführen des homogenen Gemisches durch ein Durchgangswerkzeug (25), das eine Expandierleitung einschließt, wobei das homogene Gemisch vorgeformt und expandiert wird;
   d. Durchleiten des homogenen Gemisches durch ein Strangwerkzeug (40) zur Bildung einer Mehrzahl von nebeneinander angeordneten Strängen aus dem homogenen Gemisch; und
   e. Durchleiten der Mehrzahl von Strängen durch ein Formgebungswerkzeug (78) für eine ausreichende Zeitspanne, um die Stränge aneinander zu pressen und sie miteinander zu verbinden;

   wobei das Verfahren **dadurch gekennzeichnet ist, dass** die Extrudierstufe bei einer Temperatur durchgeführt wird, die wesentlich unter der Plastifiziertemperatur des thermoplastischen Materials liegt.

2. Verfahren nach Anspruch 1, ferner umfassend die Stufe des Durchleitens des homogenen Gemisches durch ein Adapterwerkzeug (16), um das Volumen des in das Durchgangswerkzeug (25) zugelassenen homogenen Gemisches zu steuern.

3. Verfahren nach einem der vorstehenden Ansprüche, wobei jede der mehreren benachbart angeordneten Stränge eine Oberflächentemperatur aufweist, die über der Innentemperatur der einzelnen Stränge liegt.

4. Verfahren nach einem der vorstehenden Ansprüche, wobei es sich beim Strangwerkzeug um ein Werkzeug mit mehreren Öffnungen handelt, das eine Einrichtung zur Erhöhung der Temperatur der äußeren Oberfläche der einzelnen Stränge, die im Werkzeug gebildet werden, aufweist.

5. Verfahren nach einem der Ansprüche 1 bis 3, wobei das Strangwerkzeug (40) mehrere Öffnungen (42) aufweist, die so angeordnet sind, dass eine geeignete Volumenverteilung für die Stränge erleichtert wird, wobei sämtliche Öffnungen (42) im wesentlichen rund sind.

6. Verfahren nach einem der Ansprüche 4 und 5, wobei die mehreren Öffnungen (42) jeweils einen Durchmesser von etwa 3 mm (1/8 Zoll) aufweisen.

7. Verfahren nach einem der vorstehenden Ansprüche, wobei es sich beim Strangwerkzeug (40) um ein Gasevakuierungs-Strangwerkzeug handelt, das eine Einrichtung zur Erleichterung der Entfernung von unerwünschten Prozessgasen aufweist, die vorhanden sind, wenn flüchtige Vernetzungsmittel verwendet werden.

8. Verfahren nach einem der vorstehenden Ansprüche, umfassend das Durchführen der homogenen Stränge durch ein Erstarrungswerkzeug (94) für eine ausreichende Zeitspanne, um die einzelnen Stränge miteinander zu verbinden, wodurch nach Durchführen der homogenen Stränge durch das Formgebungswerkzeug (78) ein geformtes Extrudat gebildet wird.

9. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend das Abkühlen des geformten Produkte, vorzugsweise unter einem negativen Druck.

10. Verfahren nach Anspruch 9, umfassend das Besprühen des geformten Extrudats mit einer Kühlflüssigkeit, die dem geformten Extrudat einen Härtungsglanz verleiht, wobei es sich bei der Kühlflüssigkeit vorzugsweise um wasser handelt.

11. Verfahren nach Anspruch 10, umfassend das Besprühen des geformten Extrudats, bevor das Extrudat der Luft ausgesetzt wird.

12. Verfahren nach einem der vorstehenden Ansprüche, wobei das vereinigte Produkt bei einer Temperatur von etwa 65 °C (150 °F) bis 90 °C (200 °F) und vorzugsweise bei einer Temperatur von etwa 80 °C (180 °F) extrudiert wird.

13. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend das Trocknen des Cellulosematerials vor der Stufe a. auf einen Feuchtigkeitsgehalt von etwa 1 bis 9 % und vorzugsweise auf einen Feuchtigkeitsgehalt von 2 %.

14. Verfahren nach einem der vorstehenden Ansprüche, wobei das Cellulosematerial aus der Gruppe Zeitungspapier, Luzerne (Alfalfa), Weizenpulpe, Holzmehl, Holzschnipsel, Holzfasern, gemahlenes Holz, Holzfurnier, Holzlaminate, Papier, Karton, Stroh und anderen Cellulose-Fasermaterialien ausgewählt ist.

15. Verfahren nach einem der vorstehenden Ansprüche, wobei das thermoplastische Material aus der Gruppe mehrlagige Filme, Polyvinylchlorid, Polyolefine, Ethylvinylacetat und Kunststoff-Abfallsägemehl ausgewählt ist.

16. Verfahren nach einem der vorstehenden Ansprüche, wobei das Verhältnis des Cellulosematerials zum thermoplastischen Material etwa 4:1 bis 1:0 beträgt.

17. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend das Vereinigen des Cellulosematerials mit dem thermoplastischen Material in Gegenwart eines Vernetzungsmittels, wobei dieses Mittel vorzugsweise aus der Gruppe Polyurethane, Phenolharze, ungesättigte Polyester und Epoxyharze ausgewählt ist.

18. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend das vereinigen des Cellulvsematerials mit dem thermoplastischen Material in Gegenwart eines Gleitmittels, wobei das Gleitmittel vorzugsweiee aus der Gruppe Zinkstearat und Wachs vom Paraffintyp ausgewählt ist.

19. Verfahren nach einem der vorstehenden Ansprüche, ferner umfassend das Vereinigen des Cellulosematerials mit dem thermoplastischen Material in Gegenwart von einem oder mehreren der folgenden Bestandteile; Beschleuniger, Inhibitor, Verstärker, Mittel zum Verträglichmachen und Treibmittel.

20. Verfahren nach Anspruch 1, wobei das Extrudat zu mehr als 50 % aus Cellulosematerial besteht.

21. Verfahren nach Anspruch 20, wobei etwa 2/3 des Extrudate aus Cellulosematerial und etwa 1/3 aus thermoplastischem Material bestehen.

22. Verfahren nach Anspruch 21, wobei das Cellulosematerial aus der Gruppe Zeitungspapier, Luzeme (Alfalfa), Weizenmehl, Holzmehl, Holzpulpe, Holzschnipsel, Sägespäne, Holzteilchen, Papier, raffinierte Cellulose, wie Baumwolle, und Pflanzenfasern, wie Bambus, ausgewählt ist.

23. Verfahren nach Anspruch 21, wobei das thermoplastische Material aus der Gruppe mehrlagige Filme, Nahrungsmittel-Einwickelmaterialien, Polyolefine, Ethylvinylacetat und Kunststoff-Abfallsägemehl ausgewählt ist.

24. Verfahren nach einem der Ansprüche 1 bis 9 oder 20 bie 23, ferner umfassend die Stufe der Verarbeitung des Verbundstoffes unter Bildung eines Formkörpers.

25. Niedertemperatur-Extrudersystem zur Bildung eines Verbundkörperextrudats aus einem Gemisch aus einem organischen faserigen Material und einem thermoplastischen Material, umfassend:

a. einen Trichter zur Aufnahme und Bildung des Gemisches aus dem organischen faserigen Material und dem thermoplastischen Material;
b. einen Extruder (12), worin das Gemisch extrudiert wird, wobei der Extruder einen Extruderauslaß aufweist;
c. ein erstes Durchgangswerkzeug (25), umfassend eine Leitung (34) mit einem ersten Leitungsende, das an die Gestalt des Extruderauslasses angepasst ist, wobei die Leitung sich vom ersten Leitungsende zu einem zweiten Leitungsende erweitert, wobei das Gemisch expandiert und vorgeformt wird;
d. ein zweites Strangwerkzeug (40), das mit dem zweiten Leitungsende verbunden ist und mit einer Mehrzahl von durch das Strangwerkzeug gehenden Strangöffnungen (42) der gleichen Größe und von konstanter Gestalt versehen ist, um das geformte Gemisch aufzunehmen und einer Scherbehandlung unter Bildung einer Mehrzahl von einzelnen Strängen, die jeweils eine äußere Oberfläche aufweisen, zu unterziehen;
e. vin drittes Formgebungswerkzeug (78), das mit dem zweiten Strangwerkzeug (40) verbunden ist und mit einer Öffnung zur Aufnahme und zum Verpressen der einzelnen Stränge zu einer endgültigen Gestalt versehen ist; und
f. ein viertes Formgebungswerkzeug (88), das mit dem dritten Formgebungswerkzeug verbunden ist und mit

einer Extrudatform-Formgebungsöffnung zum Formen des geformten Extrudats versehen ist; und wobei die Vorrichtung ferner **gekennzeichnet ist durch**
g. eine Kontrolleinrichtung zur Steuerung der Extrusionsparameter, um die Temperatur des Extrudats unter der Plastifiziertemperatur des Extrudats zu halten.

26. Niedertemperatur-Extrudersystem nach Anspruch 25, ferner umfassend ein Adapterwerkzeug (16), das sich zwischen dem Extruder (12) und dem ersten Durchgangswerkzeug befindet, wobei das Adapterwerkzeug (16) mit einer Öffnung zur Steuerung der Menge des in das erste Durchgangswerkzeug eintretenden Gemisches versehen ist.

27. Niedertemperatur-Extrudersystem nach Anspruch 25 oder 26, wobei das erste Durchgangswerkzeug (25) eine erste Frontfläche mit einer im allgemeinen runden Öffnung und eine zweite rückwärtige Fläche mit einer Öffnung, die der Gestalt des fertigen Produkts ähnlich ist, umfasst.

28. Niedertemperatux-Extrudersystem nach einem der Ansprüche 25 bis 27, wobei das dritte Formgebungswerkzeug (78) eine erste Frontfläche, die in ihrer Gestalt der zweiten rückwärtigen Fläche des ersten Durchgangswerkzeugs (25) entspricht und eine zweite rückwärtige formbildende Fläche zur Bildung der Gestalt des geformten Extrudats aufweist.

29. Niedertemperatur-Extrudersystem nach einem der Ansprüche 25 bis 28, wobei das zweite Strangswerkzeug (40) eine erste Oberfläche (64) und eine zweite Oberfläche (68) umfasst, wobei folgende Bestandteile vorgesehen sind:

a. eine Mehrzahl von Gasevakuierungskanälen (70), die sich auf der ersten Oberfläche des zweiten Werkzeugs befinden, um Gase, die bei der Scherbehandlung des geformten Gemisches abgegeben werden, aufzunehmen und zu evakuieren; und
b. eine Mehrzahl von Gasevakuierungsöffnungen (74), die Einlässe (72) auf der ersten Oberfläche in Verbindung mit den Gaskanälen und Auslässe (76) auf der zweiten Oberfläche zur Aufnahme und zur Evakuierung von Gasen aus den Gasevakuierungskanälen aufweisen.

30. Niedertemperatur-Extudersystem nach Anspruch 29, wobei die Gasevakuierungs-Entlüftungsauslässe (76) einen größeren Umfang als die Einlässe (72) aufweisen, wodurch sich ein Venturi-Effekt ergibt, um den Gasevakuierungswirkungsgrad zu erhöhen.

31. Niedertemperatur-Extudersystem nach Anspruch 29, wobei die Gasevakuierungskanäle (70) mit den Strangöffnungen (42) in einer Gitterformation verbunden sind.

32. Niedertemperatur-Extrudersystem nach Anspruch 29, wobei die Gasevakuierungsöffnungen (74) sich im wesentlichen an einer mittleren Position zwischen den Strangöffnungen (42) befinden.

33. Niedertemperatur-Extrudersystem nach einem der Ansprüche 25 bis 32, ferner umfassend ein Sprühkopfsystem (95) zur Aufnahme des geformten Extrudats, das aus dem vierten Formgebungswerkzeug kommt.

Revendications

1. Procédé de production d'un matériau composite à partir de particules de matériau cellulosique, comportant les étapes suivantes :

a) combiner le matériau cellulosique avec une quantité suffisante de matériau thermoplastique, pour obtenir un produit combiné ;
b) extruder ce produit combiné, dans des conditions appropriées pour en faire un mélange homogène ;
c) faire passer ce mélange homogène dans une filière de transition (25) comprenant un conduit d'expansion, ce qui permet de préfaçonner le mélange homogène et de le laisser s'expanser ;
d) faire passer le mélange homogène dans une filière de formation de brins (40), pour obtenir de multiples brins de ce mélange homogène, disposés les uns à côté des autres ; et
e) faire passer ces multiples brins dans une filière de moulage (78), pendant assez longtemps pour que les brins soient comprimés les uns contre les autres et liés les uns aux autres,

ledit procédé étant **caractérisé en ce que** l'étape d'extrusion est réalisée à une température nettement inférieure à la température de plastification du matériau thermoplastique.

2. Procédé conforme à la revendication 1, qui comporte en outre une étape consistant à faire passer le mélange homogène dans une filière d'adaptation (16) qui sert à régler le volume de mélange homogène admis dans la filière de transition (25).

3. Procédé conforme à l'une des revendications précédentes, dans lequel, dans chacun des multiples brins disposés les uns à côté des autres, la température superficielle est plus élevée que la température interne.

4. Procédé conforme à l'une des revendications précédentes, dans lequel la filière de formation de brins est une filière à orifices multiples, dotée de moyens permettant d'élever la température de la surface externe de chacun des brins formés dans la filière.

5. Procédé conforme à l'une des revendications 1 à 3, dans lequel la filière de formation de brins (40) comporte de multiples orifices (42) disposés de manière à faciliter l'obtention d'une distribution volumique appropriée des brins, tous ces orifices (42) étant pratiquement circulaires.

6. Procédé conforme à l'une des revendications 4 et 5, dans lequel chacun des multiples orifices (42) présente un diamètre d'à peu près 3 mm (1/8 pouce).

7. Procédé conforme à l'une des revendications précédentes, dans lequel la filière de formation de brins (40) est une filière à évacuation de gaz, qui comporte des moyens facilitant l'évacuation des gaz de procédé indésirables qui se dégagent quand on emploie des agents de réticulation volatils.

8. Procédé conforme à l'une des revendications précédentes, qui comporte, après le passage des brins homogènes dans la filière de moulage (78), le fait de faire passer ces brins homogènes dans une filière de fixage (94) pendant assez longtemps pour que les brins individuels se lient ensemble pour constituer un extrudat moulé.

9. Procédé conforme à l'une des revendications précédentes, qui comporte en outre le fait de refroidir le produit obtenu, de préférence sous pression sub-atmosphérique.

10. Procédé conforme à la revendication 9, qui comporte le fait de pulvériser sur l'extrudat moulé un fluide réfrigérant en quantité suffisante pour donner à l'extrudat moulé une surface brillante durcie, ce fluide réfrigérant étant de préférence de l'eau.

11. Procédé conforme à la revendication 10, qui comporte le fait de pulvériser le fluide réfrigérant sur l'extrudat moulé avant que celui-ci soit exposé à l'air.

12. Procédé conforme à l'une des revendications précédentes, dans lequel le produit combiné est extrudé à une température d'environ 65 à 90 °C (150 à 200 °F), et de préférence à une température d'à peu près 80 °C (180 °F).

13. Procédé conforme à l'une des revendications précédentes, qui comporte en outre le fait de faire sécher le matériau cellulosique, avant l'étape (a), jusqu'à ce qu'il ne contienne plus qu'à peu près 1 à 9 % d'humidité, et de préférence 2 % d'humidité.

14. Procédé conforme à l'une des revendications précédentes, dans lequel le matériau cellulosique est choisi dans l'ensemble formé par les journaux, luzerne, pâte de blé, farine de bois, copeaux de bois, fibres de bois, bois broyés, bois déroulés, bois stratifiés, papiers, cartons, paille et autres matériaux cellulosiques fibreux.

15. Procédé conforme à l'une des revendications précédentes, dans lequel le matériau thermoplastique est choisi dans l'ensemble formé par les films multicouches, poly(chlorure de vinyle), polyoléfines, copolymères éthylène/acétate de vinyle et déchets de sciage de matières plastiques.

16. Procédé conforme à l'une des revendications précédentes, dans lequel le rapport du matériau cellulosique au matériau thermoplastique vaut à peu près de 4/1 à 1/0.

17. Procédé conforme à l'une des revendications précédentes, qui comporte en outre le fait de combiner le matériau

cellulosique et le matériau thermoplastique en présence d'un agent de réticulation, qui est de préférence choisi dans l'ensemble formé par les polyuréthanes, les résines phénoliques, les polyesters insaturés et les résines époxydes.

18. Procédé conforme à l'une des revendications précédentes, qui comporte en outre le fait de combiner le matériau cellulosique et le matériau thermoplastique en présence d'un lubrifiant, qui est de préférence choisi dans l'ensemble formé par le stéarate de zinc et les cires paraffiniques.

19. Procédé conforme à l'une des revendications précédentes, qui comporte en outre le fait de combiner le matériau cellulosique et le matériau thermoplastique en présence d'un ou de plusieurs des agents suivants : accélérateurs, inhibiteurs, promoteurs, agents compatibilisants et agents d'expansion.

20. Procédé conforme à la revendication 1, dans lequel l'extrudat est constitué, pour plus de 50 %, de matériau cellulosique.

21. Procédé conforme à la revendication 20, dans lequel l'extrudat est constitué d'à peu près deux tiers de matériau cellulosique et d'à peu près un tiers de matériau thermoplastique.

22. Procédé conforme à la revendication 21, dans lequel le matériau cellulosique est choisi dans l'ensemble formé par les journaux, luzerne, farine de blé, farine de bois, pâte de bois, copeaux de bois, sciure, particules de bois, papiers, cellulose raffinée telle que coton, et fibres végétales telles que fibres de bambou.

23. Procédé conforme à la revendication 21, dans lequel le matériau thermoplastique est choisi dans l'ensemble formé par les films multicouches, emballages de produits alimentaires, polyoléfines, copolymères éthylène/acétate de vinyle et déchets de sciage de matières plastiques.

24. Procédé conforme à l'une des revendications 1 à 9 et 20 à 23, qui comporte en outre le fait de soumettre ledit matériau composite à des opérations de fabrication pour en faire un article.

25. Système d'extrusion à basse température, permettant de fabriquer un extrudat moulé en matériau composite à partir d'un mélange d'un matériau organique fibreux et d'un matériau thermoplastique, lequel système comporte :

a) une trémie de réception, dans laquelle on forme le mélange de matériau organique fibreux et de matériau thermoplastique ;
b) une extrudeuse (12) dans laquelle ce mélange est extrudé et qui est munie d'une sortie ;
c) une première filière de transition (25) comportant un conduit (34) dont la première extrémité a une forme adaptée à celle de la sortie de l'extrudeuse et qui s'étend de cette première extrémité jusqu'à sa deuxième extrémité, où le mélange s'expanse et est pré-façonné ;
d) une deuxième filière de formation de brins (40), raccordée à la deuxième extrémité du conduit et pourvue de multiples orifices (42), tous de même taille et de forme constante tout le long de cette filière de formation de brins, et qui reçoit le mélange façonné et le cisaille pour en faire de multiples brins individuels présentant chacun une surface externe ;
e) une troisième filière de moulage (78), raccordée à la deuxième filière de formation de brins et pourvue d'une ouverture, et qui reçoit les brins individuels et les comprime en une forme moulée finale ; et
f) une quatrième filière de façonnage (88), raccordée à la troisième filière de moulage et pourvue d'un orifice donnant sa forme à l'extrudat, et qui façonne l'extrudat moulé ;
et est **caractérisé en ce qu'**il comporte en outre
g) des moyens de réglage qui permettent de régler les paramètres de l'opération d'extrusion de manière à maintenir la température de l'extrudat à une valeur inférieure à la température de plastification de l'extrudat.

26. Système d'extrusion à basse température, conforme à la revendication 25, qui comporte en outre, entre l'extrudeuse (12) et la première filière de transition, une filière adaptatrice (16), pourvue d'un orifice, qui permet de régler la quantité de mélange qui pénètre dans la première filière de transition.

27. Système d'extrusion à basse température, conforme à la revendication 25 ou 26, dans lequel la première filière de transition (25) comporte une première face amont, pourvue d'un orifice de forme globalement circulaire, et une deuxième face aval, pourvue d'un orifice de forme similaire à celle du produit fini.

28. Système d'extrusion à basse température, conforme à l'une des revendications 25 à 27, dans lequel la troisième filière de moulage (78) comporte une première face amont, de forme équivalente à celle de la deuxième face aval de la première filière de transition (25), et une deuxième face aval de façonnage, qui donne sa forme à l'extrudat moulé.

29. Système d'extrusion à basse température, conforme à l'une des revendications 25 à 28, dans lequel la deuxième filière de formation de brins (40) comporte une première surface (64) et une deuxième surface (68), ainsi que

a) plusieurs conduits (70) d'évacuation de gaz, situés à la première surface de la deuxième filière et destinés à recevoir et évacuer les gaz qui se dégagent lors du cisaillement du mélange façonné ; et
b) plusieurs trous (74) d'évacuation de gaz, dont les entrées (72) se situent sur la première surface et sont raccordées aux conduits d'évacuation de gaz et dont les sorties (76) se situent sur la deuxième surface, et qui sont destinés à recevoir et évacuer les gaz qui viennent des conduits d'évacuation de gaz.

30. Système d'extrusion à basse température, conforme à la revendication 29, dans lequel la circonférence des sorties (76) des trous d'évacuation de gaz est plus grande que celle de leurs entrées (72), ce qui génère un effet de Venturi qui rend plus efficace l'évacuation des gaz.

31. Système d'extrusion à basse température, conforme à la revendication 29, dans lequel les conduits (70) d'évacuation de gaz sont raccordés aux orifices (42) de la filière de formation de brins et disposés en un quadrillage.

32. Système d'extrusion à basse température, conforme à la revendication 29, dans lequel les trous (74) d'évacuation de gaz sont situés à peu près à équidistance des orifices (42) de la filière de formation de brins.

33. Système d'extrusion à basse température, conforme à l'une des revendications 25 à 32, qui comporte en outre un dispositif à tête de pulvérisation (95), destiné à recevoir l'extrudat moulé provenant de la quatrième filière de façonnage.

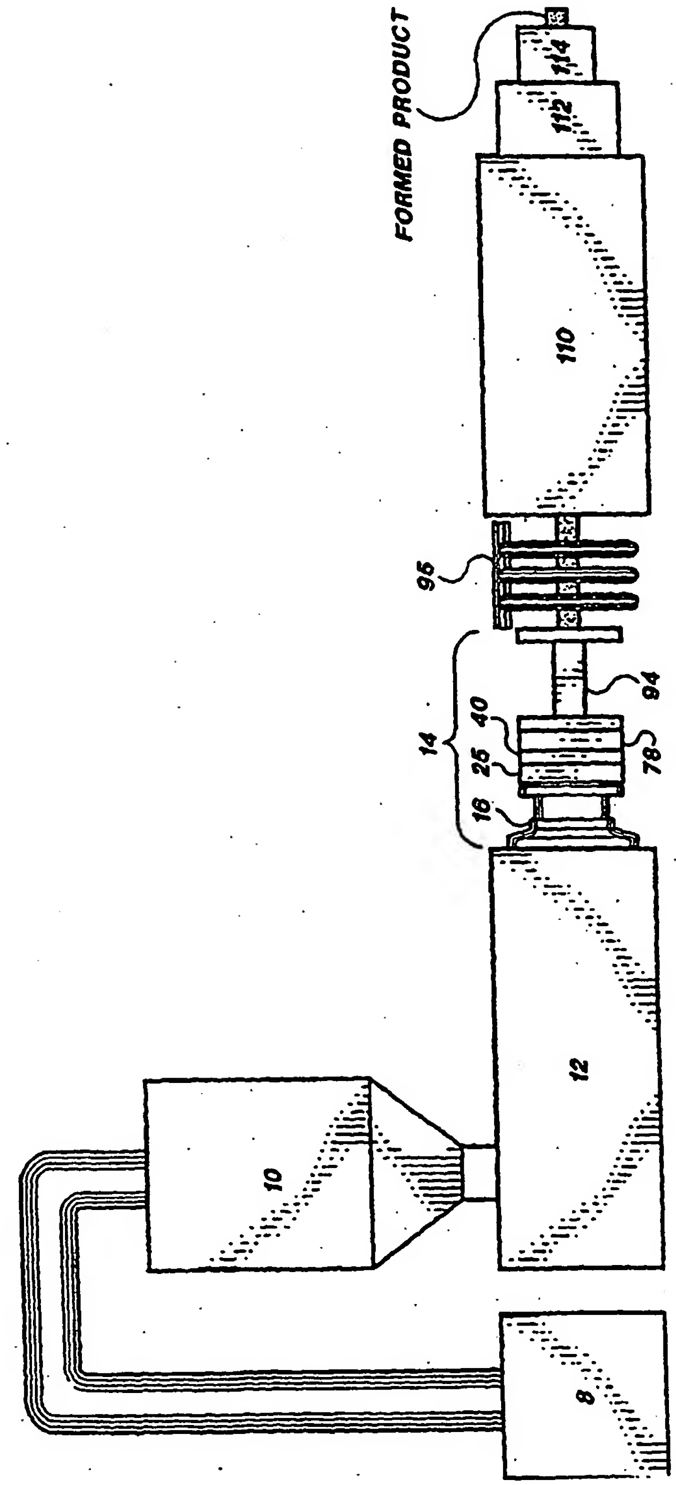

FIG. 1

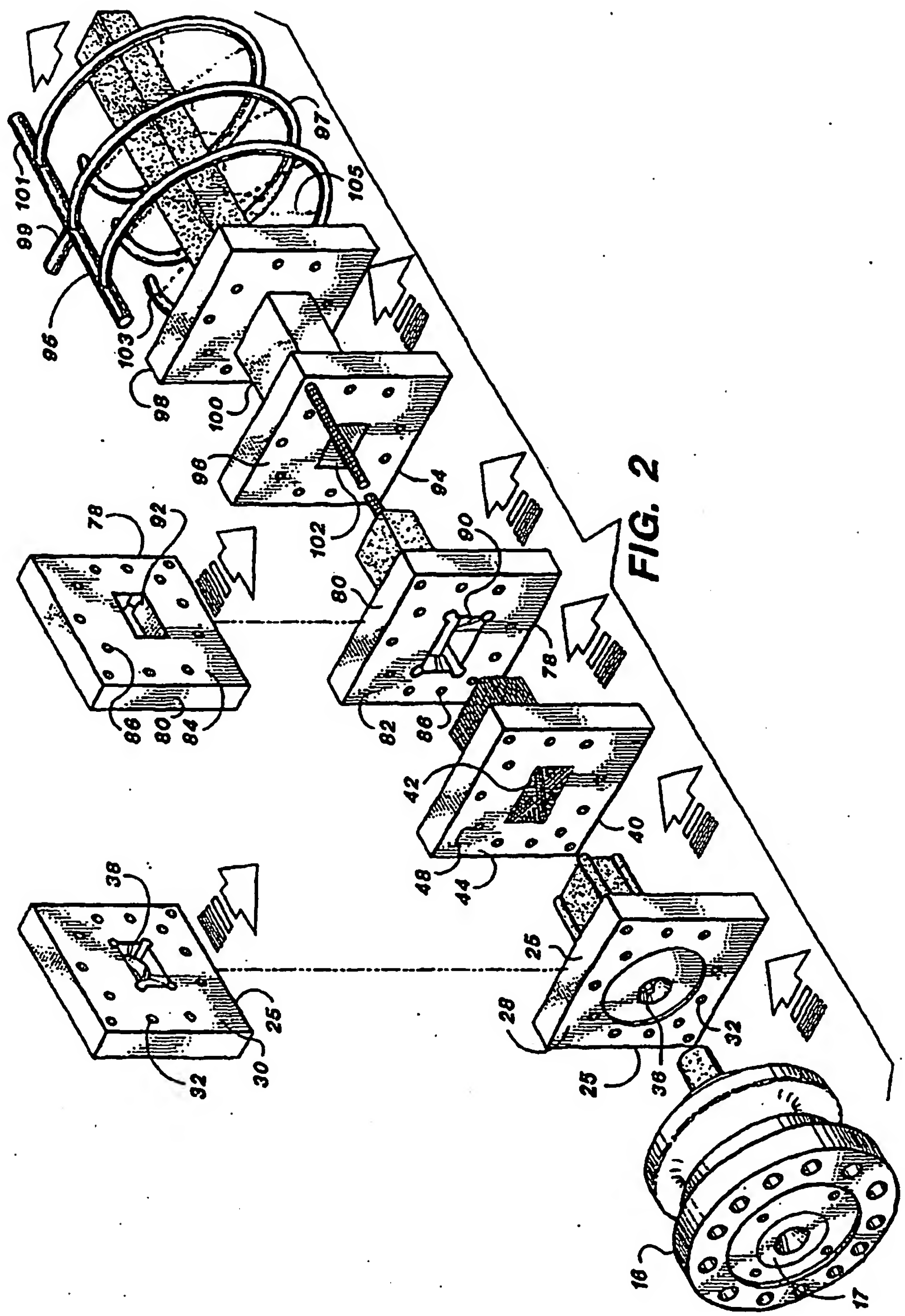

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FIG. 2

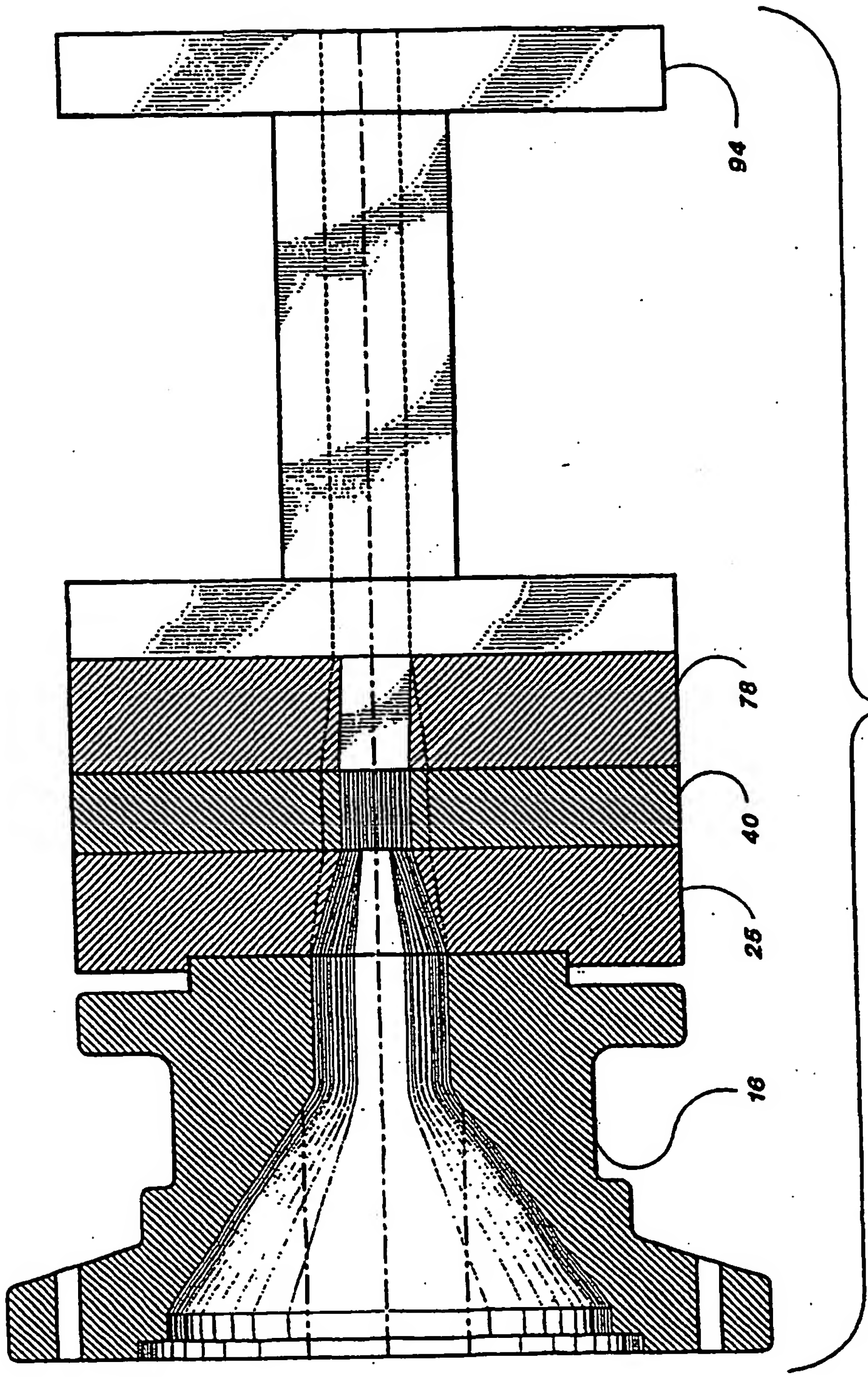

FIG. 3

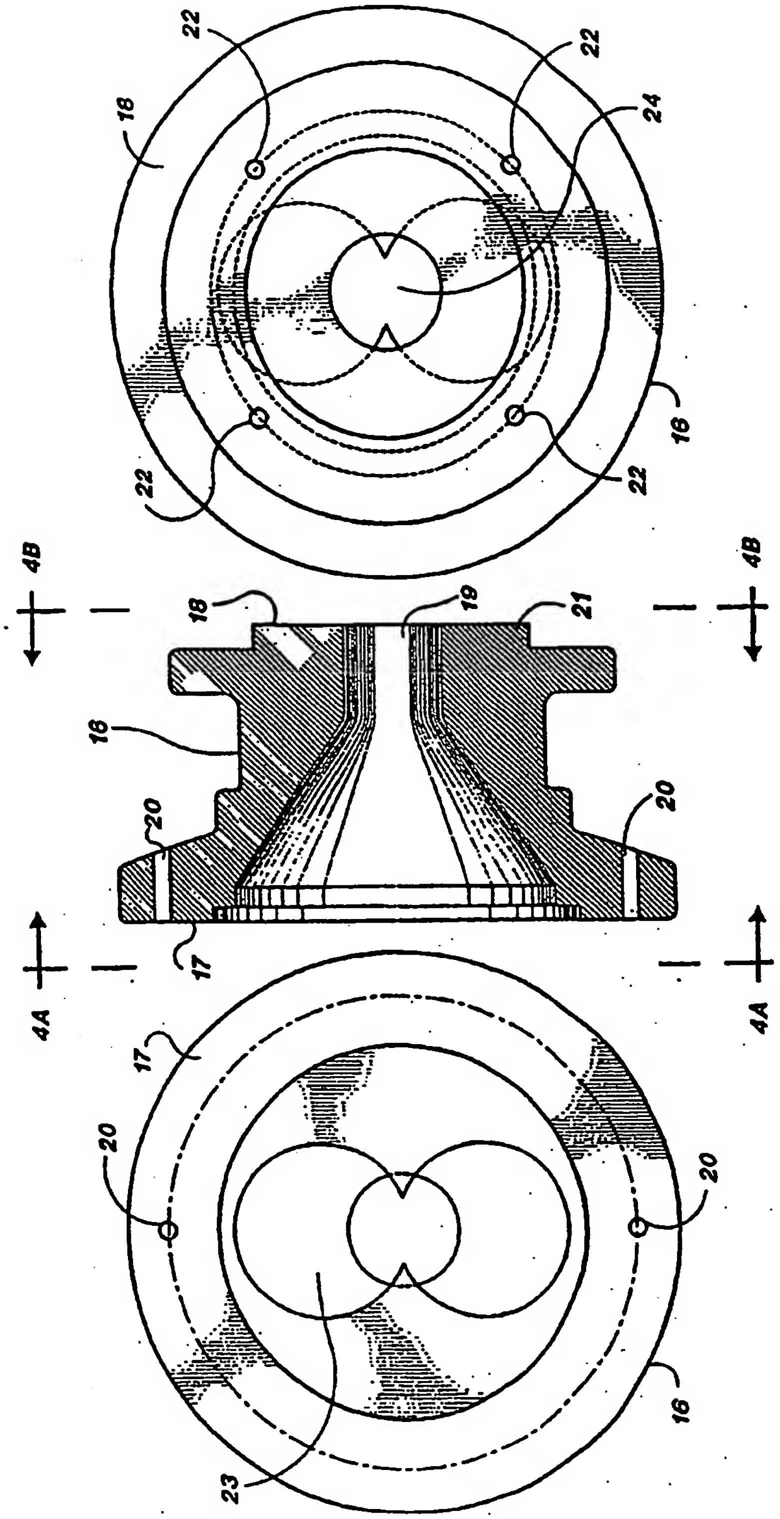

FIG. 4B

FIG. 4

FIG. 4A

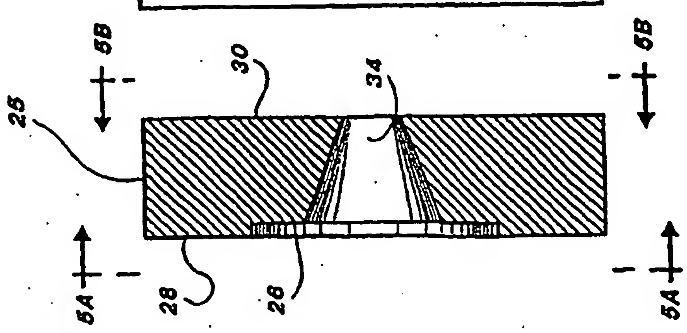

FIG. 5

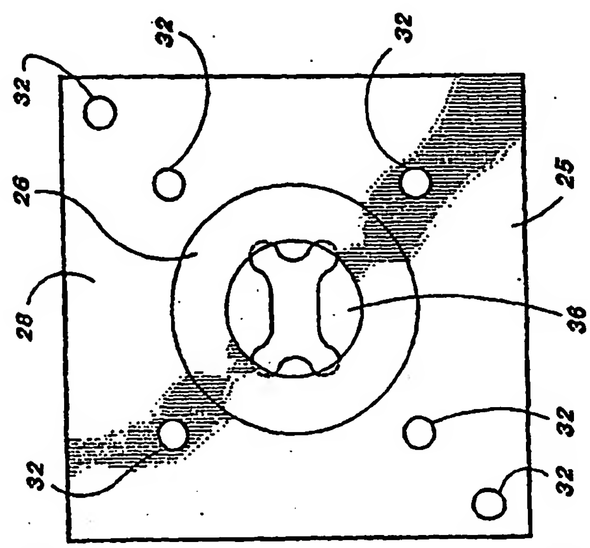

FIG. 5A

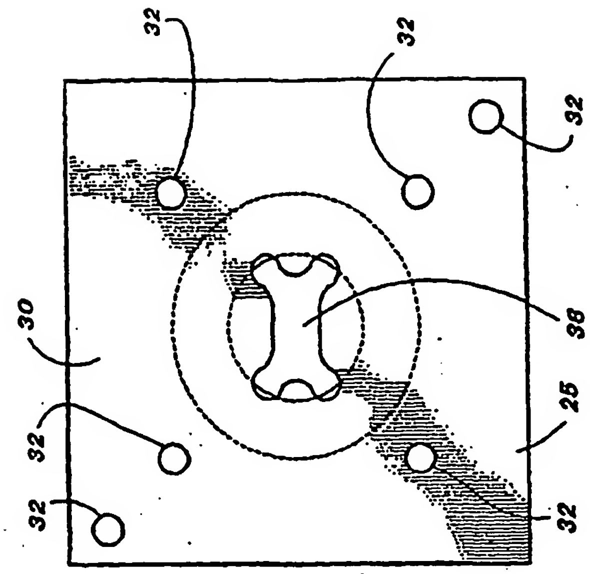

FIG. 5B

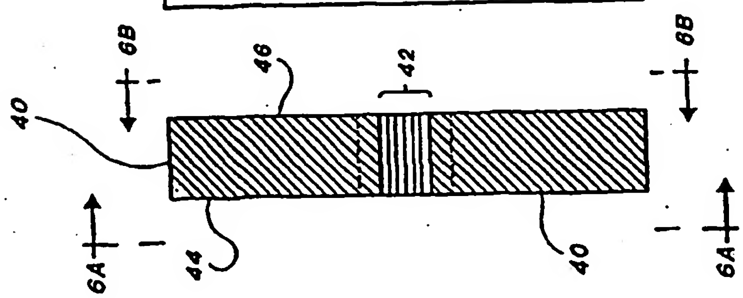

FIG. 6

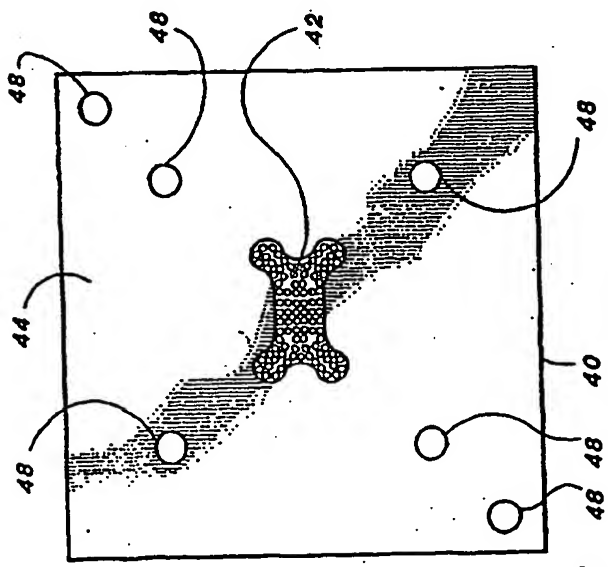

FIG. 6A

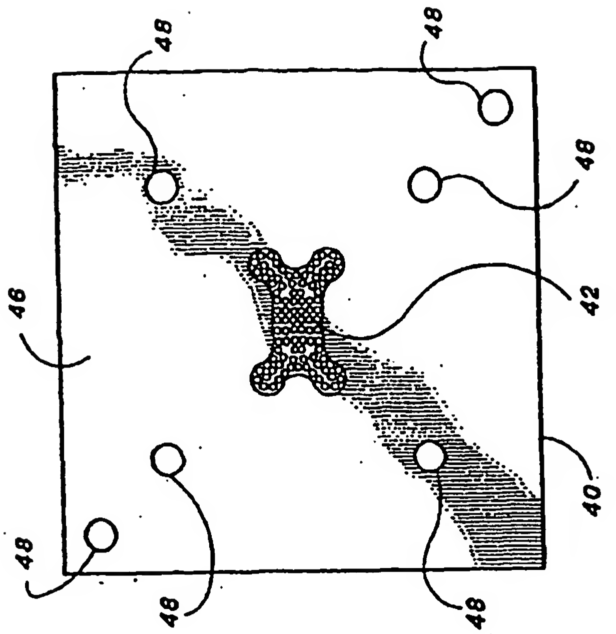

FIG. 6B

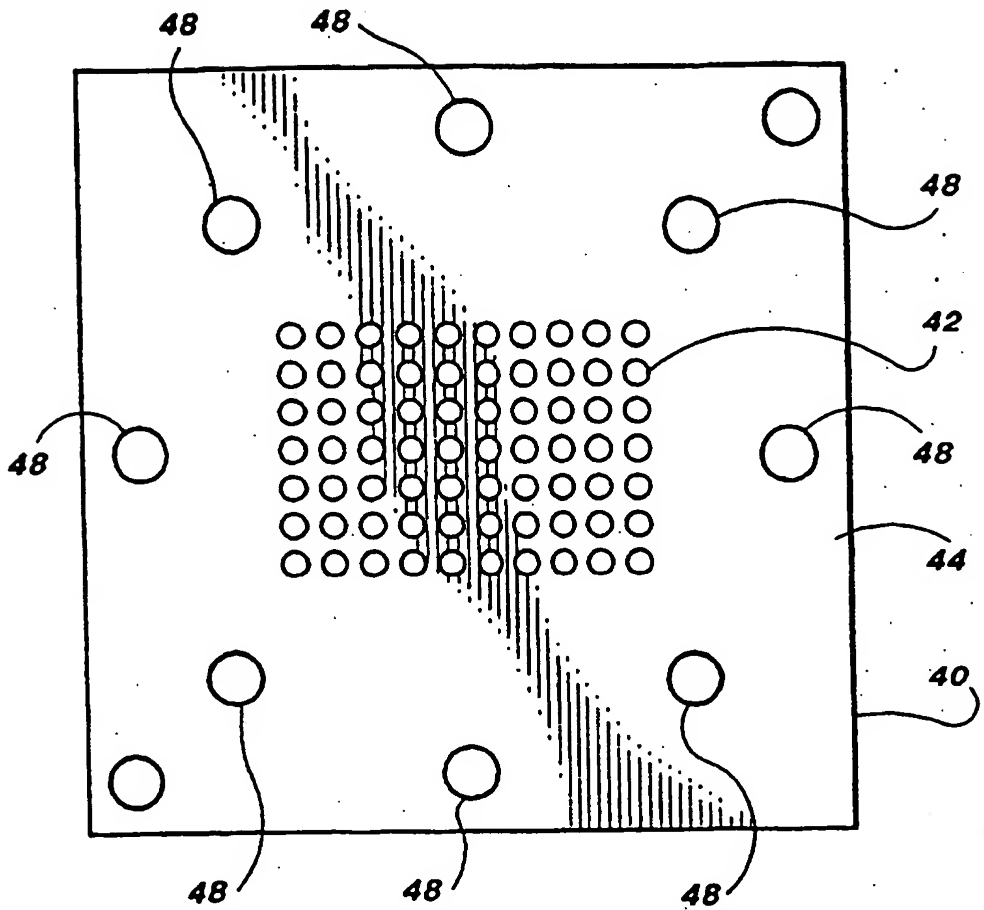

FIG. 6C

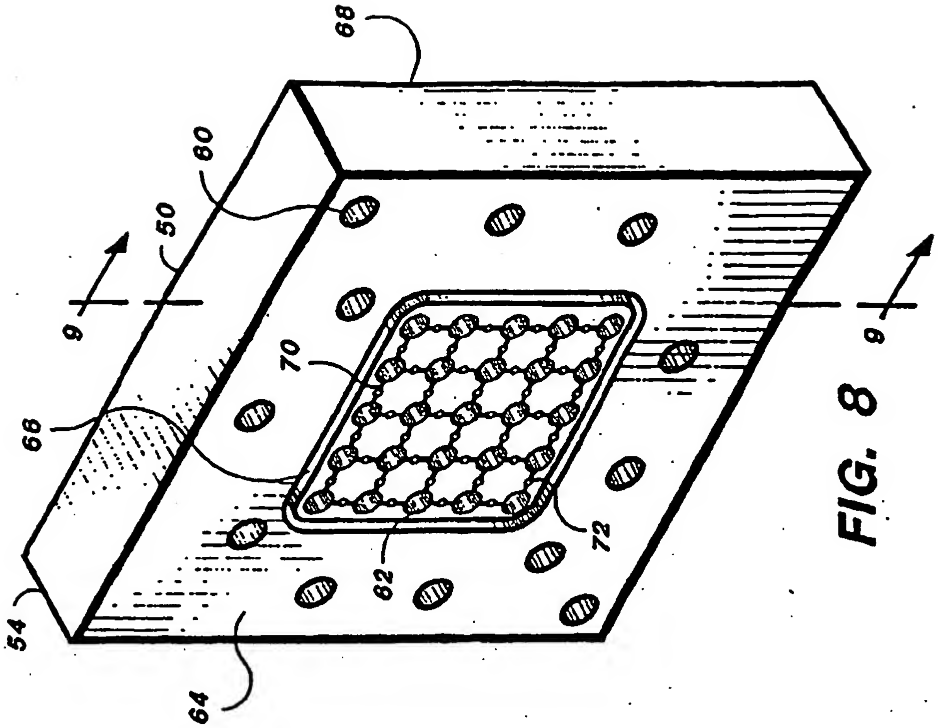

FIG. 8

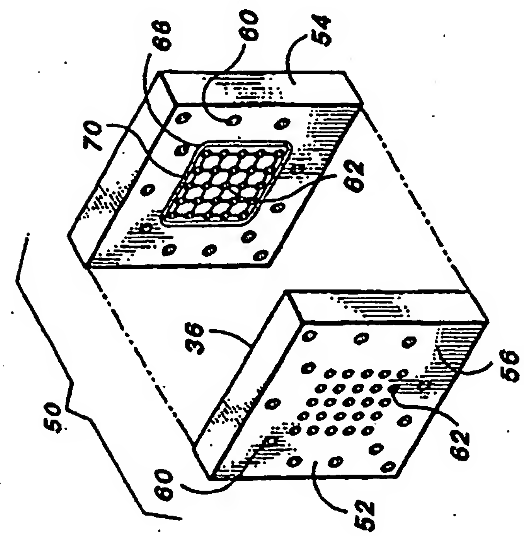

FIG. 7

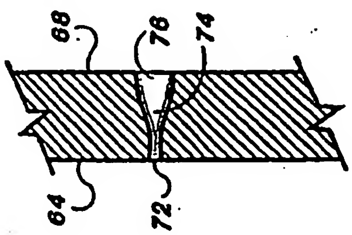

FIG. 9

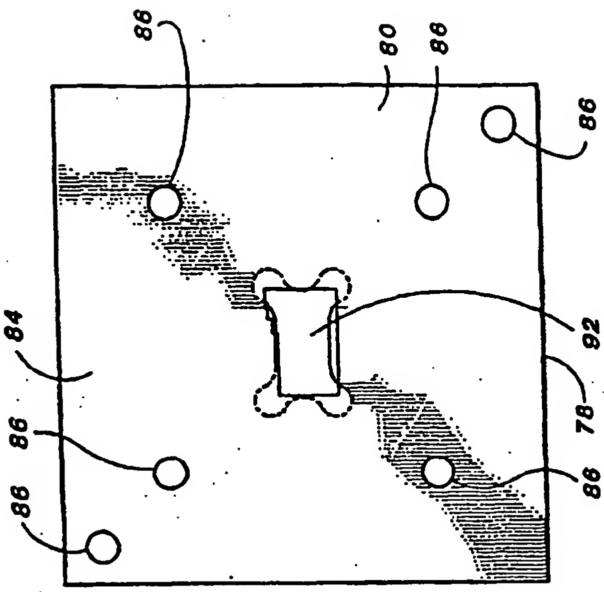

FIG. 10B

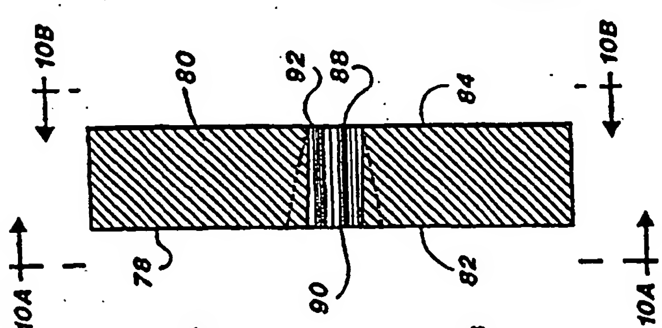

FIG. 10

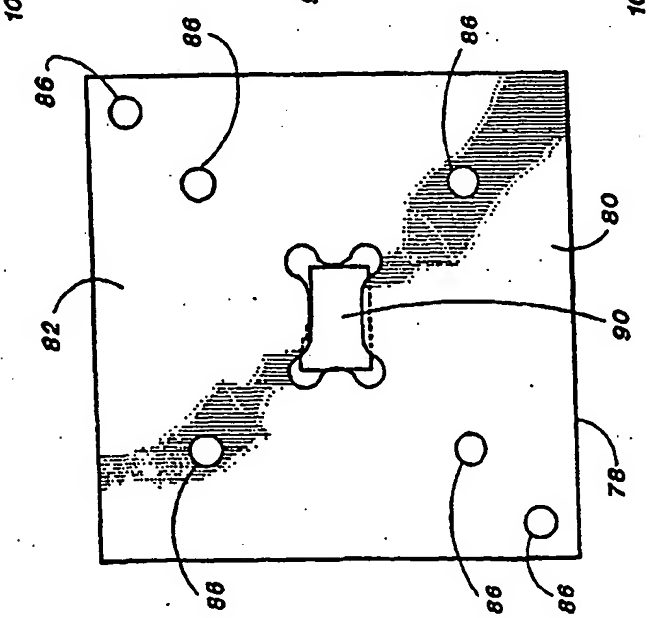

FIG. 10A

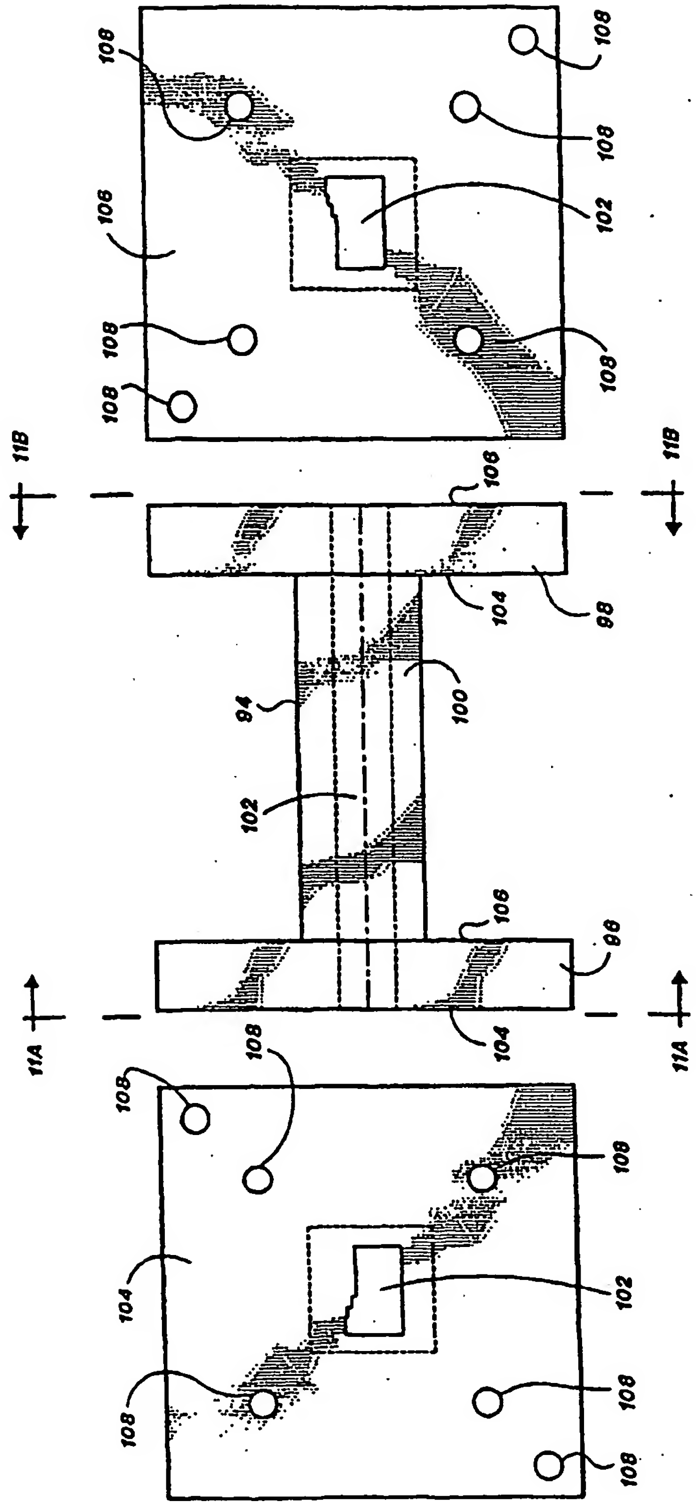

FIG. 11B

FIG. 11

FIG. 11A

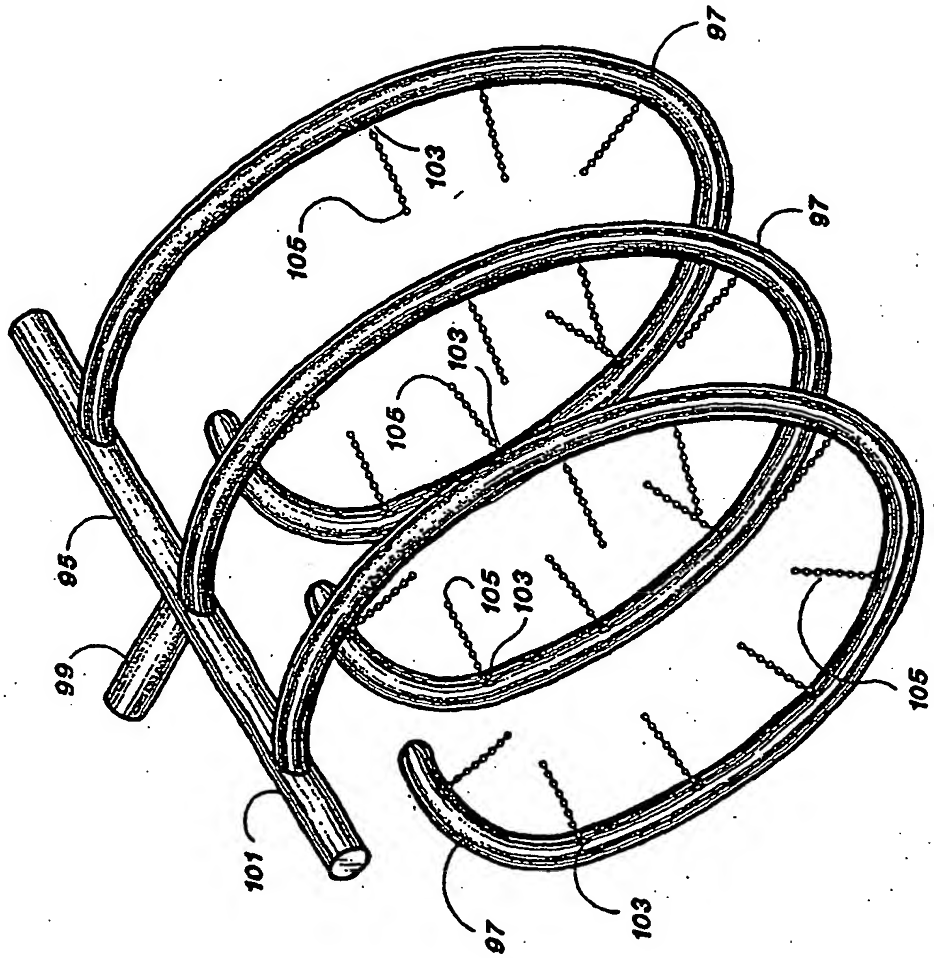

FIG. 12